# Appendix F

# Basis for the Diesel PM Standards

## Introduction

This appendix presents the basis for the diesel particulate matter (PM) limits established in the proposed *Stationary Diesel-Fueled Engine Airborne Toxic Control Measure* (ATCM).

The diesel PM emission limits established for engines greater than 50 horsepower are summarized in Table F-1. The diesel PM emission limit for engines less than or equal to 50 hp is equal to the applicable Off-Road Compression-Ignition Engine Standards (Title 13, CCR, section 2423). Altogether, there are six different diesel PM limits established by the ATCM. Each limit represents the application of what ARB staff considers the best available control technology (BACT) for a specific category of engine and engine use. Factors that influence what "best available control technology" means for a specific category and use of engine include potential near source risk, cost of controls, the availability of control technologies that can be used to meet these limits, and the availability of new engines that can meet these limits. The following paragraphs explain ARB staff's rationale for establishing these each of these limits.

**Table F-1: Diesel PM Limits for Engines Greater than 50 Horsepower**

| Diesel PM Emission Limit | Applicability | | | | | | Comments/Notes |
|---|---|---|---|---|---|---|---|
| | Prime | | E/S | | Agricultural | | |
| | New | In-Use | New | In-Use | New | In-Use | |
| None | | | | X | | | • For E/S: Annual maintenance and testing hours limited to 20 or less |
| ≤0.40 | | | | X | | | • For E/S: Annual maintenance and testing hours limited to 30 or less |
| ≤0.15 | | | X | X | X | | • For E/S: Annual maintenance and testing hours limited to 50 or less |
| ≤0.01 | X | X | X | X | | | • For E/S: Annual maintenance and testing hours limited to 100 or less |
| 30% reduction from baseline levels | | X | | | | | • For Prime: Must meet 0.01 g/bhp-hr by 2011 |
| 85% reduction from baseline levels | | X | | | | | |

**Diesel PM Limit: None (No diesel PM limit established)**

*To what engine applications does this diesel PM limit apply?*

In-use emergency standby engines that are operated less than or equal to 20 hours per year for maintenance and testing purposes.

*Why is this limit appropriate for these applications?*

For in-use engines, those that have been installed at a facility on or before January 1, 2005, the most cost effective approaches to reducing the risk to acceptable levels is to limit the hours of operation. ARB staff knows from reviewing air dispersion modeling (see Appendix E, Stationary Diesel-Fueled Engines, Health Risk Assessment Methodology) results that engine horsepower or size does not have as significant an impact on the maximum offsite risk as does diesel PM emission rate and hours of operation. Our modeling showed that most engines could operate for 10 to 20 hours per year without exceeding a potential cancer case threshold of 10 potential cancer cases per million.

The results from the ARB survey of emergency standby diesel-fueled CI engines in California indicate that on average a typical stationary engine operates approximately 20 hours per year for maintenance and testing, with 95 percent of the engines operating 50 hours or less for maintenance and testing purposes (See Appendix B, Stationary Emergency Standby Diesel-Fueled Engine Survey). From this data, ARB staff concludes that it is technically feasible to reduce hours of operation for maintenance and testing to below 20 hours per year. Results from that same survey indicate that on average an emergency standby engine operates 7 hours per year for emergency use, with over 80 percent of the engines operating 10 hours or less for emergency use. Therefore, ARB staff believes a limit on maintenance and testing hours of operation is appropriate because these hours of operation are planned hours of operation and represent the mode of operation where the most hours are accumulated. The owner or operator has control over how long these engines are run in this mode, while emergency use hours by definition are unplanned and are typically much less than the scheduled hours of operation for maintenance and testing.

**Diesel PM Limit: 0.40 g/bhp-hr**

*To what engine applications does this diesel PM limit apply?*

In-use emergency standby engines that are operated less than or equal to 30 hours per year for maintenance and testing purposes.

*Why is this limit appropriate for these applications?*

Although the reduction in planned hours of operation is the simplest and most cost effective way to reduce the risk in-use emergency standby engines, ARB staff recognizes that there may be specific applications that require more than 20 hours of operation per year for maintenance and testing. Therefore, ARB staff has established requirements that consist of both emission limits and limits on annual hours of operation. Our air dispersion modeling shows that most engines that emit diesel PM at an emission rate of 0.40 g/bhp-hr could operate for up to 30 hours per year without exceeding a potential cancer case threshold of about 10 potential cancer cases per million at the point of maximum impact.

As discussed in the previous subsection, ARB survey data indicates that is technically feasible for many owners to reduce their hours of operation for maintenance and testing to below 30 hours per year, and that a limit on maintenance and testing hours of operation is appropriate because these hours of operation are planned hours of operation and represent the mode of operation where the most hours are accumulated. The owner or operator has control over how long these engines are run in this mode, while emergency use hours by definition are unplanned and are typically much less than the scheduled hours of operation for maintenance and testing.

*Is the 0.40 g/bhp-hr diesel PM emission limit technologically achievable?*

The 0.40 g/bhp-hr is technologically achievable because:

- Off-road Certified Engines with horsepower ratings from 100 to 175 have been required to meet a 0.22 g/bhp-hr standard since 2003.
- Off-road Certified Engines with horsepower ratings from 175 to 750 have been required to meet a 0.40 g/bhp-hr standard since 1996.
- Off-road Certified Engines with horsepower ratings greater than 750 have been required to meet a 0.40 g/bhp-hr standard since 2000.
- Three pre-1996 model year engines were tested for diesel PM emission rate as part of the ARB/CE-CERT Diesel PM Control Technology Demonstration. All three engines emitted diesel PM at levels below 0.40 g/bhp-hr, the highest being 0.19 g/bhp-hr.
- Diesel PM emission test results from the ARB/CE-CERT Diesel PM Control Technology Demonstration (see appendix H, Control Technology Demonstration.) and independent testing have shown diesel oxidation catalyst (DOC) technology can reduce diesel PM emissions from 20 to 30 percent. A typical uncontrolled diesel-fueled engine currently operating in California emits between 0.50 and 0.60 g/bhp-hr of diesel PM. An engine with a baseline diesel PM emission rate of 0.55 would be able to meet the 0.40 g/bhp-hr standard if it installed a DOC with a reduction efficiency of 27 percent.

**Diesel PM Limit: 0.15 g/bhp-hr**

*To what engine applications does this diesel PM limit apply?*

- New and in-use emergency standby engines that are operated less than or equal to 50 hours per year for maintenance and testing purposes.

- New agricultural engines.

*Why is this limit appropriate for these applications?*

New and In-Use Emergency Standby Engine Applications

As discussed in the previous subsection, ARB staff's approach in defining BACT for in-use emergency standby engine applications has been to establish emission rate limits and planned hours of operation limits that, together, result in an acceptable level of risk. Our air dispersion modeling shows that most engines that emit diesel PM at an emission rate of 0.15 g/bhp-hr could operate for up to 50 hours per year without exceeding a potential cancer case threshold of 10 potential cancer cases per million. For all new emergency standby engines, those installed after January 1, 2005, the 0.15 g/bhp-hr standard is appropriate, because new engines meeting this standard are currently available "off-the-shelf".

As discussed in the previous subsection, ARB survey data indicates that is technically feasible for many owners to reduce their hours of operation for maintenance and testing to well below 50 hours per year, and that a limit on maintenance and testing hours of operation is appropriate because these hours of operation are planned hours of operation and represent the mode of operation where the most hours are accumulated. The owner or operator has control over how long these engines are run in this mode, while emergency use hours by definition are unplanned and are typically much less than the scheduled hours of operation for maintenance and testing.

Agricultural Engines

The proposed ATCM establishes performance standards for new agricultural engines similar to new emergency standby engines, but without hour of operation restrictions for agricultural engines that are used in as emergency standby engines. Both new emergency standby and new prime engines used in agricultural operations are required to meet the 0.15 g/bhp-hr diesel PM emission limit. The "cleanest" off-road certified engines currently produced meet the 0.15 g/bhp-hr diesel PM certification level. Requiring agricultural engines to meet more stringent standards would mean the application of retrofit technologies. At this time, ARB staff believes that it is not appropriate to require the application of diesel PM emission control retrofit technologies on new or in-use agricultural

engines. The reasons for this include the current lack of off-the-shelf retrofit control technology kits that could easily be installed by individual farmers; implementation and enforcement constraints resulting from the current lack of permitting requirements for agricultural engines; and the potential for creating disincentives to replacing or discontinuing the use of older, dirtier engines

A major factor in staff's decision not to require retrofit controls for new or in-use agricultural engines is retrofit installation and availability issues. Engine manufacturers currently are not producing engines with add-on PM controls for off-road applications. The purchaser of a new agricultural engine would have to arrange to have retrofit controls installed after purchase. It would be very difficult for the individual farmer or the local engine dealer to arrange for installation of retrofit controls since it is currently not an option offered by the engine manufacturer. Staff believes that to successfully implement retrofits requirements for engines in agricultural service, bolt-on retrofit kits design by the engine manufactured will be needed.

In addition to the retrofit installation and availability issue, there is an implementation and enforcement issue regarding new and in-use agricultural engines. Health and Safety Code section 42310 exempts any equipment used in agricultural operations from having to obtain a permit. Staff believes that it would be extremely difficult and resource intensive to implement retrofit control requirements without a permitting system. Requiring a permit provides a mechanism for obtaining critical data on engine location, make/model, model year, horsepower, and operating hours. More importantly, it provides an enforceable mechanism for the district to obtain the information necessary to determine if the selected equipment is capable of meeting the requirements of the ATCM. Because of the permitting restriction, staff believes that the best approach is to require new agricultural engine to meet the lowest achievable off-road engine standards and to not require retrofits on in-use agricultural engines.

Finally, staff is also concerned that requiring retrofit control for new engines would provided a disincentive for replacing older, dirtier engines. Currently a large number of older agricultural engines have been replaced with newer engines meeting the 0.15 g/bhp-hr PM standard under the Carl Moyer program. Requiring retrofit controls would increase the cost of a new engine by 25 to 40 percent, making it less likely that older engines would be replaced. Requiring retrofit controls would also require more Moyer funds to be spent on fewer engines. Due to increased costs, we believe that requiring retrofit controls on in-use engines may make it less likely that these engines will be removed from service and replaced with electric power. We believe that replacing diesel engines with electric power may be the best long term approach for reducing PM and NOx emission from stationary agricultural engines.

*Is the 0.15 g/bhp-hr diesel PM emission limit technologically achievable?*

The 0.15 g/bhp-hr is technologically achievable because

- Newly manufactured off-road engines less than 175 hp are held to less stringent standards, but certification data indicate that approximately 18 percent of the off-road certified engines emitted diesel PM at a rate less than or equal to 0.15 g/bhp-hr.
- Off-road Certified Engines with horsepower ratings from 175 to 299 have been required to meet a 0.15 g/bhp-hr standard since 2003.
- Off-road Certified Engines with horsepower ratings from 300 to 599 have been required to meet a 0.15 g/bhp-hr standard since 2000.
- Off-road Certified Engines with horsepower ratings greater than 600 to 750 have been required to meet a 0.15 g/bhp-hr standard since 2002.
- Seven stationary diesel-fueled engines were tested for diesel PM emission rate as part of the ARB/CE-CERT Diesel PM Control Technology Demonstration (see Appendix H, Control Technology Demonstration). Of the seven, two of the engines emitted diesel PM at a rate less than or equal to 0.15 g/bhp-hr. The remaining five were retrofitted with different diesel PM control technologies. These control technologies included emulsified fuels, active and passive diesel particulate filter systems, and diesel oxidation catalysts. All five engines were tested after the control technologies were implemented and all five engines emitted diesel PM at levels below 0.15 g/bhp-hr.

**Diesel PM Limit: 0.01 g/bhp-hr**

*To what engine applications does this diesel PM limit apply?*

- New and in-use emergency standby engines that are operated less than or equal to 100 hours per year for maintenance and testing purposes.
- New and in-use prime engines

*Why is this limit appropriate for these applications?*

<u>New and In-Use Emergency Standby Engine Applications</u>

As discussed in the previous subsections, ARB staff's approach in defining BACT for new and in-use emergency standby engine applications has been to establish emission rate limits and planned hours of operation limits that, together, result in an acceptable level of risk. Our air dispersion modeling shows that most engines that emit diesel PM at an emission rate of 0.01 g/bhp-hr could operate for up to 100 hours per year without exceeding a potential cancer case threshold of about one potential cancer case per million.

As discussed in the previous subsection, ARB survey data indicates that is technically feasible for many owners to reduce their hours of operation for maintenance and testing to well below 100 hours per year, and that a limit on maintenance and testing hours of operation is appropriate because these hours of operation are planned hours of operation and represent the mode of operation where the most hours are accumulated. The owner or operator has control over how long these engines are run in this mode, while emergency use hours by definition are unplanned and are typically much less than the scheduled hours of operation for maintenance and testing.

New and In-Use Prime Engines

Defining BACT for prime engine applications differs from emergency standby applications because prime engines have no limit on their hours of operation. Therefore, ARB staff had to establish BACT based solely on diesel PM emission rate. Our air dispersion modeling shows that most engines that emit diesel PM at an emission rate of 0.01 g/bhp-hr could operate for up to 1000 hours per year without exceeding a potential cancer case threshold of about 10 potential cancer case per million. According to survey response information, the average hours of operation for a stationary prime diesel-fueled CI engine is approximately 1000 hours per year. (See Appendix C, Stationary Prime Diesel-Fueled Engine Survey.)

*Is the 0.01 g/bhp-hr diesel PM emission limit technologically achievable?*

The 0.01 g/bhp-hr is technologically achievable because

- Two stationary diesel-fueled engines that were tested for diesel PM emission rate as part of the ARB/CE-CERT Diesel PM Control Technology Demonstration were able to achieve a diesel PM emission rate of equal to or less than 0.01 g/bhp-hr through the application of DPF technologies.
- In support of its Verification application to the ARB, CleanAIR Systems has submitted diesel-fueled CI engine emission test data that shows its Passive DPF technology, the PERMIT technology, is capable of diesel PM emission rate reductions of 85 percent and greater, and has resulted in reducing diesel-fueled CI engine emission rates to below 0.01 g/bhp-hr. (ARB, 2003)

**Diesel PM Limit: 30 percent reduction from baseline levels**

*To what engine applications does this diesel PM limit apply?*

- In-use prime engines that are not certified in accordance with the Off-Road Compression Ignition Engine Standards (title 13, CCR, section 2423).

*Why is this limit appropriate for these applications?*

The "30 percent reduction, by weight, from baseline levels" option is one part of a two-part standard that is applicable only to in-use, uncertified engines. Owners that choose this option for compliance are required to meet the 30 percent reduction by no later than January 1, 2006, and then meet a more stringent standard of 0.01 g/bhp-hr by July 1, 2003. ARB staff believes this option will be used by owners of older, uncertified engines that may have difficulty in meeting the 85 percent reduction requirement by the compliance dates specified in the proposed ATCM. This is especially true of older, two-stroke engines with baseline diesel PM emission rates above 0.40 g/bhp-hr, relatively cooler average exhaust temperatures (less than 300 C) and relatively higher fractions (above 30 percent) of the diesel PM comprised of soluble organics. Owners of these engines may opt to reduce their diesel PM emissions by at least 30 percent through the application of diesel emission control systems that are based on the use of a diesel oxidation catalyst. (DieselNet, 2002)

Although the short-term risk from engines that choose to meet this two-part standard will be greater than those that meet the 85 percent reduction limit by the compliance dates specified in the proposed ATCM (January 2006-2009), ARB staff's believes the additional risk reductions associated with reducing the diesel PM emission rate of these engines to 0.01 g/bhp-hr by 2011 will result in an overall reduction in risk benefit over the lifetime of the engine.

*Is the 30 percent reduction diesel PM emission standard technologically achievable?*

The 30 percent reduction, by weight, diesel PM standard is technologically achievable because:

- A 1985 two-stroke Detroit Diesel V92 equipped with a diesel oxidation catalyst was tested as part of the ARB/CE-CERT Diesel PM Control Technology Demonstration, and was able to achieve a diesel PM emission rate reduction of 47 percent, by weight. (See Appendix H, Control Technology Demonstration.)
- Diesel oxidation catalysts are the most common currently used form of diesel aftertreatment technology and have been used for compliance with the PM standards for on-highway diesel-fueled engines since the early 1990's.

**Diesel PM Limit: 85 percent reduction from baseline levels**

*To what engine applications does this diesel PM limit apply?*

- In-use prime engines

*Why is this limit appropriate for these applications?*

In establishing the diesel PM emission standards for in-use prime engines, ARB staff recognized that not all of these engines will be able to meet the 0.01 g/bhp-hr emission standard. Although the ARB/CE-CERT Diesel PM Control Technology Demonstration and the Verification program has shown that the 0.01 g/bhp-hr emission standard is achievable by in-use engines retrofitted with diesel particulate filter technologies, these engines had baseline diesel PM emission rates that were 0.15 g/bhp-hr and less. (See Appendix H, Control Technology Demonstration.) For engines with emission rates that are greater than 0.15 g/bhp-hr., the 0.01 g/bhp-hr standard may not be achievable. However, ARB staff believes that an 85 percent reduction in diesel PM emission rates is achievable for most in-use diesel-fueled engines. This is consistent with the test information summarized in the Risk Reduction Plan to Reduce Particulate Emissions from Diesel-Fueled Engines and Vehicles, October 2000.

*Is the 85 percent reduction, by weight, PM emission limit technologically achievable?*

- In support of its Verification application to the ARB, CleanAIR Systems has submitted diesel-fueled CI engine emission test data that shows its Passive DPF technology, the PERMIT technology, is capable of diesel PM emission rate reductions of 85 percent and greater, and has resulted in reducing diesel-fueled CI engine emission rates to below 0.01 g/bhp-hr.
- Two stationary diesel-fueled engines that were tested for diesel PM emission rate as part of the ARB/CE-CERT Diesel PM Control Technology Demonstration were able to achieve a diesel PM emission rate reduction of at least 85 percent, by weight, through the application of DPF technologies.

**REFERENCES:**

California Air Resources Board. *Letter from Robert H. Cross, Mobile Source Control Division, to Dr. Mike Tripodi, CleanAIR Systems, Reference # RAS-03-19*; June 6, 2003. (ARB, 2003)

DieselNet. *Technology Guide: Diesel Oxidation Catalyst*; 2002. (DieselNet, 2002)